

AN ANALYSIS OF SOME DIFFERENCES  
BETWEEN ONE AND TWO-HANDED  
INDUSTRIAL WORK

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AN ANALYSIS OF SOME DIFFERENCES BETWEEN  
ONE AND TWO-HANDED INDUSTRIAL WORK

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A Thesis

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In Partial Fulfillment of the

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in

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## ACKNOWLEDGMENT

The author wishes to express his gratitude to the many persons who have contributed much of their time and effort in making this study possible.

Much credit is due Professors H. T. Amrine and W. J. Richardson for their valuable advice, suggestions, and encouragement. It was through them also that access was gained into the plants in which the studies were made.

The author is indebted to the Colgate-Palmolive-Peet Company, Jeffersonville, Indiana, the Duncan Electric Company, Lafayette, Indiana, and the Stephen A. Young Company, Flora, Indiana, for making available their personnel and facilities. Sincere appreciation is extended to the personnel, both in the offices and the shops, for their assistance and cooperation without which this study would not have been possible.

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The author is indebted to the following companies, for their cooperation, advice, and facilities: the American Electric Company, Indianapolis, and the American A. Young Company, Ellettsville, Indiana, for making available their personnel and facilities. Kinross Corporation is thanked for the personnel, both in the office and the plant, for their assistance and cooperation without which this study would not have been possible.



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ABSTRACT

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The purpose of this report is to present the results of a study of the effect of the amount of light on the growth of a certain type of plant. The study was conducted in a greenhouse where the amount of light was varied by means of different colored glass panes. The results show that the amount of light has a significant effect on the growth of the plant. The plant grown under the most light conditions showed the greatest growth, while the plant grown under the least light conditions showed the least growth. The results of this study are of interest to those who are interested in the effect of light on plant growth.

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## ABSTRACT

In the system of stop watch time study advanced by Dr. M. E. Mundel<sup>1</sup> the rating of an operator's performance is based upon a comparison between the pace or rate of activity of the operator and a standard rate of activity. A correction is then applied for what are now termed allowances and secondary adjustments.<sup>2</sup> One of these secondary adjustments is made for bimanualness or bimanual activity. For the purpose of this discussion a bimanual operation is defined as one requiring the simultaneous symmetrical motion of both hands.

Previous studies<sup>3</sup> conducted at the University of Iowa show a difference in cycle time between one and two handed operations of approximately 30%. The adjustment now applied for bimanual activity is 10% based on the above figure tempered by judgement and experience in application. It was the purpose of this study to substantiate the previous research in part and to determine a more nearly correct value for this adjustment.

It was intended in this experiment to minimize the

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1. M. E. Mundel, Systematic Motion and Time Study; (New York, Prentice Hall, 1947) p. 128.
  2. M. E. Mundel, Motion and Time Study Principles and Practice; (New York, Prentice Hall, 1950) Chapter 18 (Manuscript before press.)
  3. R. M. Barnes, M. E. Mundel, and J. M. MacKenzie, "Studies of One and Two-Handed Work," (University of Iowa Studies in Engineering, Bulletin 21, 1940).



In the system of stop watch time study introduced by Dr. W. L. Lumsden, the rating of an operator's performance is based upon a comparison between the pace or rate of activity of the operator and a standard rate of activity. A correction is then applied for what are now termed allowances and secondary adjustments. One of these secondary adjustments is made for dissimilarity of physical activity. For the purpose of this discussion a dissimilarity operation is defined as one requiring the simultaneous symmetrical motion of both hands.

Previous studies conducted at the University of Iowa show a difference in cycle time between one and two handed operations of approximately 30%. The adjustment now applied for dissimilarity activity is based on the above figure tempered by judgment and experience in application. It was the purpose of this study to substantiate the previous research in part and to determine a more nearly correct value for this adjustment.

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1. W. L. Lumsden, Systematic Motion and Time Study; (New York, Prentice Hall, 1937) p. 124.

2. W. L. Lumsden, Motion and Time Study Principles and Practice; (New York, Prentice Hall, 1950) Chapter 10 (Secondary Adjustments).

3. W. L. Lumsden, W. L. Lumsden, and J. M. Macdonald, "Studies of One and Two-Handed Work," University of Iowa Studies in Engineering, Vol. 11, No. 1, 1940.

error in the previous laboratory study believed attributable to inexperience and laboratory conditions. For that reason the subjects in this study were experienced operators doing industrial jobs requiring bimanual activity. A total of eight operators on five different operations were selected. Each operator performed the operation first bimanually, then with the preferred hand alone and finally with the non-preferred hand. A short practice period was included between each phase.

Each study was recorded on 16 mm. motion picture film with time included by means of having a microchronometer placed in the field of view. This procedure made possible a very accurate determination of cycle time. A sufficient number of cycles were photographed to obtain a statistically reliable mean cycle time for each operation.

From the mean of the cycle times there was calculated a percent increase in cycle time required for bimanual activity over that required using the preferred hand. The mean percent increase in cycle time was found to be 17.852%. Since the percent increase in cycle time is symmetrically distributed about the mean, the mean is the best measure of central tendency.<sup>4</sup> It is concluded then that a value of 18% is more nearly the correct adjustment to be applied for bimanualness.

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4. P. G. Hoel, Introduction to Mathematical Statistics; (New York, Wiley and Sons, Inc., 1947) p. 8, 18.

error in the previous laboratory study believed attributable to inexperience and laboratory conditions. For these reasons the subjects in this study were experienced operators using industrial John Deere diesel engine. A total of eight operators on five different operations were selected. Each operator performed the operation three times.

When the operator had done and timing with the non-rotated hand, a single position period was indicated by a green light.

When study was recorded on 10 cm. motion picture film with time indicated by means of timing - at continuous places in the field of view. This procedure made possible a very accurate determination of cycle time. A continuous number of cycles were photographed in order to obtain a total of 10 cycles when cycle time for each position.

From the mean of the cycle times were calculated a percent increase in cycle time required for the hand activity over that required using the rotated hand. The mean percent increase in cycle time was found to be 17.8%. Since the percent increase in cycle time is systematically distributed about the mean, the mean is the best measure of central tendency. It is concluded that that a value of 17.8 is more nearly the correct adjustment to be applied to the data.



# AN ANALYSIS OF SOME DIFFERENCES BETWEEN ONE AND TWO-HANDED INDUSTRIAL WORK

## INTRODUCTION

"Stop watch time study is used to find the amount of time necessary to accomplish a unit of work using a given method under given conditions of work, by a worker possessing a specified amount of skill on the job and a specified aptitude for the job, when working at a pace that will produce, within a unit of time, a specified physical effect upon him."<sup>1</sup>

There are four principal steps in the mechanics of taking a stop watch time study, namely:

1. Recording the method.
2. Recording the time.
3. Rating the operator.
4. Application of allowances and secondary adjustments.

It is a very small portion of the fourth step listed which is the subject of this study.

In the system of stop watch time study<sup>2</sup> advanced by Dr. M. E. Mundel, rating, which is the third step mentioned in the preceding paragraph, is accomplished by relating

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1. Mundel, Systematic, p. 128.

2. Ibid.

## INTRODUCTION

Stop watch time study is said to find the amount of time necessary to accomplish a unit of work using a given method under given conditions of work, by a worker possessing a specified amount of skill on the job and a specified aptitude for the job, when working at a rate that will produce, within a unit of time, a specified quantity of product upon him.<sup>1</sup>

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1. Lumsden, *Systematic*, p. 128.

2. *Ibid.*



the performance of an operator to a standard by a comparison of pace alone. The fallacy of such a system without secondary adjustments for job difficulty is apparent when one considers the following exaggerated case. Suppose the rate of activity of a worker handling fifty pound weights is compared to that of a man dealing cards as a standard. Due to job difficulty the pace at which the former works cannot possibly approach that rate of activity which is the standard. An adjustment is therefore made to the rating for the degree of job difficulty - in this case the weight handled. In a like manner, but to a lesser degree, an adjustment must be made for bimanual activity.

In studies<sup>3</sup> conducted at Iowa University there was found to be an increase in cycle time of approximately 30% when performing a simple operation bimanually over that needed to perform the operation with only one hand. From experience in the application of the adjustment for bimanualness it has been determined that a value of 30% is too great and an adjustment of 10% is now being used.

An examination of the Iowa studies suggests that the error believed to be included in the results might be attributed to a lack of experience on the part of the operators. The operators were students whose performances were recorded after a minimum of training. Equal training or practice periods were allocated to each phase of

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3. Barnes, Mundel, MacKenzie, Op. Cit.

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In studies<sup>2</sup> conducted at Iowa University there was  
 found to be an increase in cycle time of approximately 50%  
 when performing a single operation continuously over time  
 needed to perform the operation with only one hand. This  
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the study. The operators performed the operation first with only one hand and then bimanually. Although the operation was a relatively simple one, it is possible that a marked degree of proficiency was attained using only one hand and that the same degree of proficiency was not reached in the bimanual operation.

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 a method beyond of redundancy was attempted using only one  
 hand and that the same degree of proficiency was not reached  
 in the bimanual operation.

It is not surprising, therefore, that the operators who  
 learned to perform the task with one hand were able to  
 perform the task with two hands. The operators who  
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## PURPOSE

The purpose of this investigation is to determine the adjustment for bimanualness which should be applied in making a stop watch time study when using a pace-rating system.



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The purpose of this investigation is to determine the effectiveness for diamondstone which should be applied in some kind of a study which would be a good thing to do.

## PROCEDURE

This experiment was designed primarily to eliminate lack of experience as a factor influencing the results. Operators were selected who had considerable experience or who demonstrated the equivalent in aptitude and proficiency on bimanual jobs in industry. It appears reasonable to conclude that these operators must possess equal skill in using only one hand separately to do the identical job. Any lack of familiarity or awkwardness in performing the job with one hand was minimized by allowing short practice periods for the operators.

In addition it was intended to minimize all variables except those which are uniquely attributable to bimanual activity. Jobs were selected which required a minimum of eye-hand coordination in order to minimize the effect of that variable for which a separate correction is made. The weights of parts handled by the operator were negligible and no part of the cycle was machine paced. It might appear that a wide range of job cycle times is desirable for a study of this kind. However, all but two jobs selected had comparatively short cycle times. A short cycle was characteristic of the jobs from which the selection for this study was made and is typical of a wide variety of bimanual jobs. Eight operators on five different jobs were selected.

Once the operator was selected, the purpose, procedure

This experiment was designed primarily to investigate lack of experience as a factor influencing the results. Operators were selected who had considerable experience in who demonstrated the equivalent in aptitude and proficiency on standard jobs in industry. It appears reasonable to conclude that these operators must possess equal skill in using only one hand separately to do the identical job. Any lack of facility or awkwardness in performing the job with one hand was minimized by allowing each practice period for the operators.

In addition it was intended to minimize all variables except those which are uniquely attributable to bilateral activity. Jobs were selected which required a minimum of eye-hand coordination in order to eliminate the effect of that variable for which a separate experiment is made. The weights of parts handled by the operator were negligible and no part of the cycle was machine time. It might appear that a wide range of job cycle times is desirable for a study of this kind. However, all but two jobs selected had comparatively short cycle times. A short cycle was characteristic of the jobs from which the selection for this study was made and is typical of a wide variety of standard jobs. Eight operators on five different jobs were selected.

Once the operator was selected, the purpose, procedure



and scope of the study were explained to him. He was instructed to perform each phase of the study using exactly the same method and at the maximum pace which he could attain. He was assured that the motion pictures would not be used by the company in setting standards or in any way which would affect the job either directly or indirectly. The operator was given an opportunity to ask any questions he wished concerning the procedure and objectives of the study. In that way it was attempted to obtain the complete confidence and cooperation of the operator before the study was begun.

The operator first performed the operation bimanually, then with the preferred hand, and finally with the non-preferred hand. A brief practice period was allocated between each phase to enable the operator to become adapted to performing the operation with only one hand. The operator's performance was recorded using a motion picture camera. A sufficient number of cycles were photographed to insure a statistically reliable average cycle time.

The motion pictures were taken on Eastman Kodak Super XX film at 16 frames per second using an Eastmen Kodak Cine Special 16 mm. camera with an f 1.9 lens. Photoflood lights were used to supplement the light normally available to the worker in order to insure satisfactory exposures. A microchronometer was placed in the field of view of the camera in order to provide a measure of time on the film. The film is available for reference in the Motion and Time

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 study was begun.

The operator first performed the operation manually,  
 then with the prepared hand, and finally with the non-  
 prepared hand. A brief practice period was allowed be-  
 fore each phase to enable the operator to become adapted  
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The motion pictures were taken on Eastman Kodak Super  
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 Cine Special 16 mm. camera with an f.1.5 lens. Sufficient  
 lights were used to supplement the light normally available  
 to the worker in order to insure satisfactory exposures.  
 A microchronometer was placed in the field of view of the  
 camera in order to provide a measure of time on the film.  
 The film is available for reference in the motion picture



Study Laboratory, Purdue University.

After the film was processed, it was analyzed. For this work, a small, inexpensive, hand-crank operated motion picture projector was used to view the film in a darkened room. The projector was fitted with a heat dispensing adaptor in order that a single frame could be viewed for any length of time without danger of burning the film. The analysis consisted of determining and recording the time required for each cycle. Those cycles were not included which incorporated fumbles or irregularly occurring elements not inherent in the operation. The procedure used in analyzing the film was to pick out a well defined therblig<sup>4</sup> in the operation and record the time value shown on the microchronometer each time that therblig occurred. The difference between the successive time values becomes the cycle time which was computed and recorded.

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4. Mundel, Systematic, p. 105.



## DATA

The data for this study consists of a tabulation of the cycle times required by each operator to perform his particular operation bimanually, with the preferred hand, and with the non-preferred hand. These tables, Tables 3 through 10, and job descriptions, Figures 3 through 7, appear in the Appendix.

In each case a sufficient number of cycles were photographed to obtain a statistically reliable mean cycle time for each set of data. In order to substantiate this, one has only to apply the formula:<sup>5</sup>

$$N' = \left( \frac{40\sqrt{N\sum t^2 - (\sum t)^2}}{\sum t} \right)^2$$

where,

$N^1$  = the number of cycles required to establish the probability that 95 times out of 100 the average cycle time will be within  $\pm 5\%$  of the true average representing the observed performance.

$N$  = the number of cycles recorded.

$t$  = the individual cycle times.

For each set of data  $N^1$  was found to be smaller than  $N$ , and thus the reliability of the mean at the 5% level was established. The 5% confidence level is an industrially

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5. M. E. Mundel, "How Many Readings in a Time Study," ("Modern Management" August, 1949).



The data for this study consists of a compilation of the cycle times recorded by each operator in various industrial operations. The data was collected from the records of the various departments of the company. The data was collected from the records of the various departments of the company. The data was collected from the records of the various departments of the company.

In each case a sufficient number of cycles were observed to obtain a statistically reliable mean cycle time for each set of data. In order to substantiate this, the data was analyzed by the following formula:

$$W = \left( \frac{40 \sqrt{N \sum d^2 - (\sum d)^2}}{\sum d} \right)^2$$

where:  
 $N$  = the number of cycles recorded in each set of data  
 $d$  = the individual cycle times  
 $\sum d$  = the sum of the individual cycle times  
 $\sum d^2$  = the sum of the squares of the individual cycle times

The mean cycle time for each set of data was found to be within 1% of the true mean cycle time. The 95% confidence level is an industrially

U. S. Bureau of Standards, "The Study of Industrial Operations," Report, 1940.

accepted standard. For mathematical computations see  
Table 11.





## RESULTS

The mean cycle time required by each operator for each phase of the operation is recorded in Table 1.

Table 1  
MEAN JOB CYCLE TIMES.  $\bar{t}$

Operation	Operator	Mean Cycle Time (winks)		
		Bi-manually	Preferred Hand	Non-preferred Hand
1	1	36.000	30.893	31.710
	2	34.333	28.210	28.270
	3	40.133	33.051	33.088
2	1	34.895	30.463	31.571
	2	45.357	35.000	40.533
3	1	41.621	38.147	40.625
4	1	250.167	222.818	222.000
5	1	177.452	150.850	156.667

A wink is a 1/2000th part of a minute.

From the above results there was computed the percent increase in cycle time required when performing bimanually and when using the non-preferred hand over that required when using the preferred hand. That information is shown in Table 2.

The mean cycle time required by each operator for each phase of the operation is recorded in Table 1.

Table 1  
MEAN CYCLE TIME

Operator	Operator	Mean Cycle Time (secs)	Mean Cycle Time (secs)
1	2	1	2
31.77	30.98	30.00	30.98
28.27	28.20	24.25	28.20
33.08	33.01	40.12	33.01
31.47	30.48	34.88	30.48
40.58	38.00	43.37	38.00
40.52	38.17	41.81	38.17
32.00	32.00	30.17	32.00
30.57	30.57	17.43	30.57

A week is a 1/200th part of a minute.

From the above results there was computed the increase in cycle time required when performing the operation and when using the non-reversed hand over the reversed hand. This information is shown in Table 2.

Table 2

PERCENT INCREASE IN CYCLE TIME  
OVER PREFERRED HAND TIMES

Operation	Operator	Bimanually	Non-Preferred Hand
1	1	16.531	2.645
	2	21.705	0.213
	3	21.427	0.112
2	1	14.549	3.637
	2	29.591	15.808
3	1	9.107	6.496
4	1	12.274	-0.368
5	1	17.635	3.856

The mean percent increase in cycle time for bimanual operation over that required using the preferred hand alone is determined from the above to be 17.852%.



Table 2

PERCENT INCREASE IN CYCLE TIME  
OVER PREVIOUS YEAR

Operation	Operation	Operation	Operation
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9
10	10	10	10

The mean percent increase in cycle time for bimodal operation over that reported using the preferred head alone is determined from the above to be 17.55%.

## DISCUSSION OF RESULTS

Since the cycle times in two of the eight jobs studied were comparatively long, it was believed desirable to see what effect, if any, the length of cycle time had upon the percent increase in cycle time. A simple correlation coefficient between the two was calculated using the formula:

$$r = \frac{N\sum xy - \sum x \sum y}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}}$$

$$= 0.34$$

This correlation coefficient is not significantly different from zero and, therefore, there is little correlation between the two items. To further substantiate this result a line of least squares was calculated for this data and was found to have a slope of +.029. The scattergram for this data is shown in Figure 1. For mathematical computations see Table 12.

A histogram showing the frequency distribution of the percent increase in cycle times in the class intervals 0-5%, 5-10%, 10-15%, 15-20%, 20-25% and 25-30% is shown in Figure 2. It is clearly evident that the observed values are quite symmetrically distributed about the mean which was found to be 17.852% and that, therefore, the mean value is the best measure of central tendency.<sup>6</sup>

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6. Hoel, loc. cit.

Since the cycle times in two of the other tests varied more comparatively long, it was believed desirable to use about equal, if not, the length of cycle times and upon the percent increase in cycle times. A simple correlation coefficient between the two was calculated using the formula:

$$r = \frac{N\sum xy - \sum x \sum y}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}}$$

$$= 0.54$$

This correlation coefficient is not statistically different from zero and, therefore, there is little correlation between the two items. The further substantiated this result a line of least squares was calculated for this data and was found to have a slope of +0.07. The scattergram for this data is shown in Figure 1. For mathematical comparison see Table 12.

A histogram showing the frequency distribution of the percent increase in cycle times in the same intervals 0-5%, 5-10%, 10-15%, 15-20%, 20-25% and 25-30% is shown in Figure 2. It is clearly evident that the observed values are quite symmetrically distributed about the mean value and found to be 17.38% and 23.0%, therefore, the mean value is the best measure of central tendency.

This value of 18% is clearly significantly different from the 30% which was previously found in the Iowa studies.<sup>7</sup> It is indeed probable that the major contributing factor to that difference is the inexperience of the operators in the previous experiment. That factor has been minimized in the present study. It is concluded that the 18% increase in cycle time is due almost entirely to what might be termed difficulty of coordination in bimanual activity.

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7. Barnes, Mundel, and McKenzie, op. cit.





## CONCLUSIONS

Since it has been shown that an average operator requires 18% longer to complete a cycle bimanually than when using only one hand, it follows that he must be operating at a pace 18% slower in the former case. Yet in each case he was performing at a rate of activity which represented his maximum effort. Therefore, the rating assigned to the operators performance should be identical in both instances. Using pace alone as a criterion, however, the operator when performing bimanually would be rated 18% lower than when using only the preferred hand. To make the ratings identical, a correction of 18% must be added to the rating assigned to the bimanual operation. Therefore, it is concluded that a secondary adjustment of 18% must be made to compensate for job difficulty in bimanual operations using a pace-rating system of time study.

... Since it has been shown that an average operator per-  
forms the same number of errors as a highly skilled operator when  
working on a task, it follows that he must be operating  
at a pace 10% slower in the former case. But in such  
cases he was performing at a rate of activity which was  
within the normal limits. Therefore, the results obtained  
for the operators performance should be identical in both  
instances. Using pace alone as a criterion, however, the  
operator when performing bimurally would be rated 10%  
lower than when using only the preferred hand. To make  
the results identical, a correction of 10% must be added  
to the rating assigned to the bimural operation. There-  
fore, it is concluded that a necessary adjustment of 10%  
must be made to compensate for the difficulty in bimural  
operation using a two-handed system of time study.

## APPENDIX





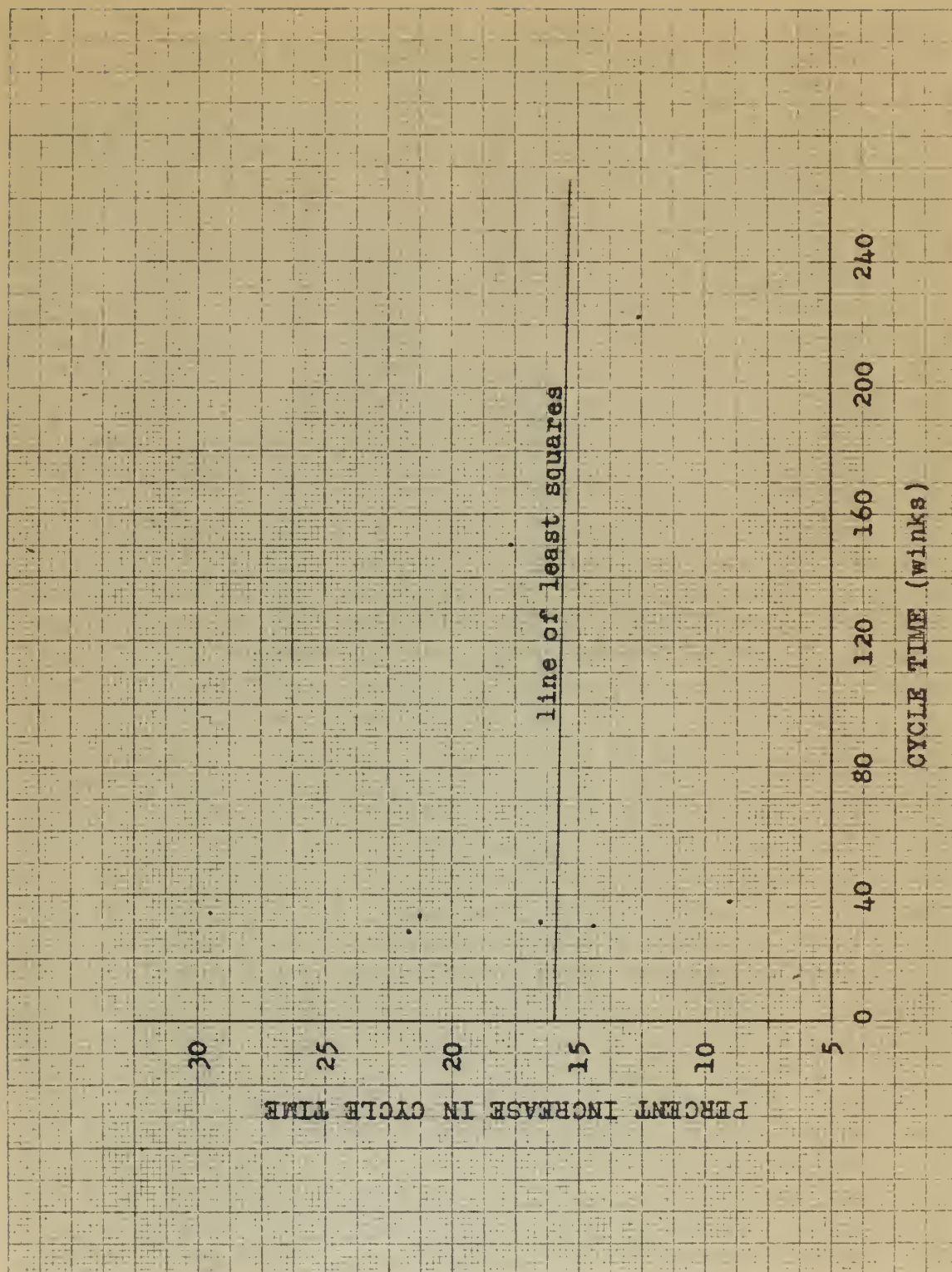


Figure 1. Mean cycle time vs. percent increase in cycle time for bimanual over preferred hand activity.



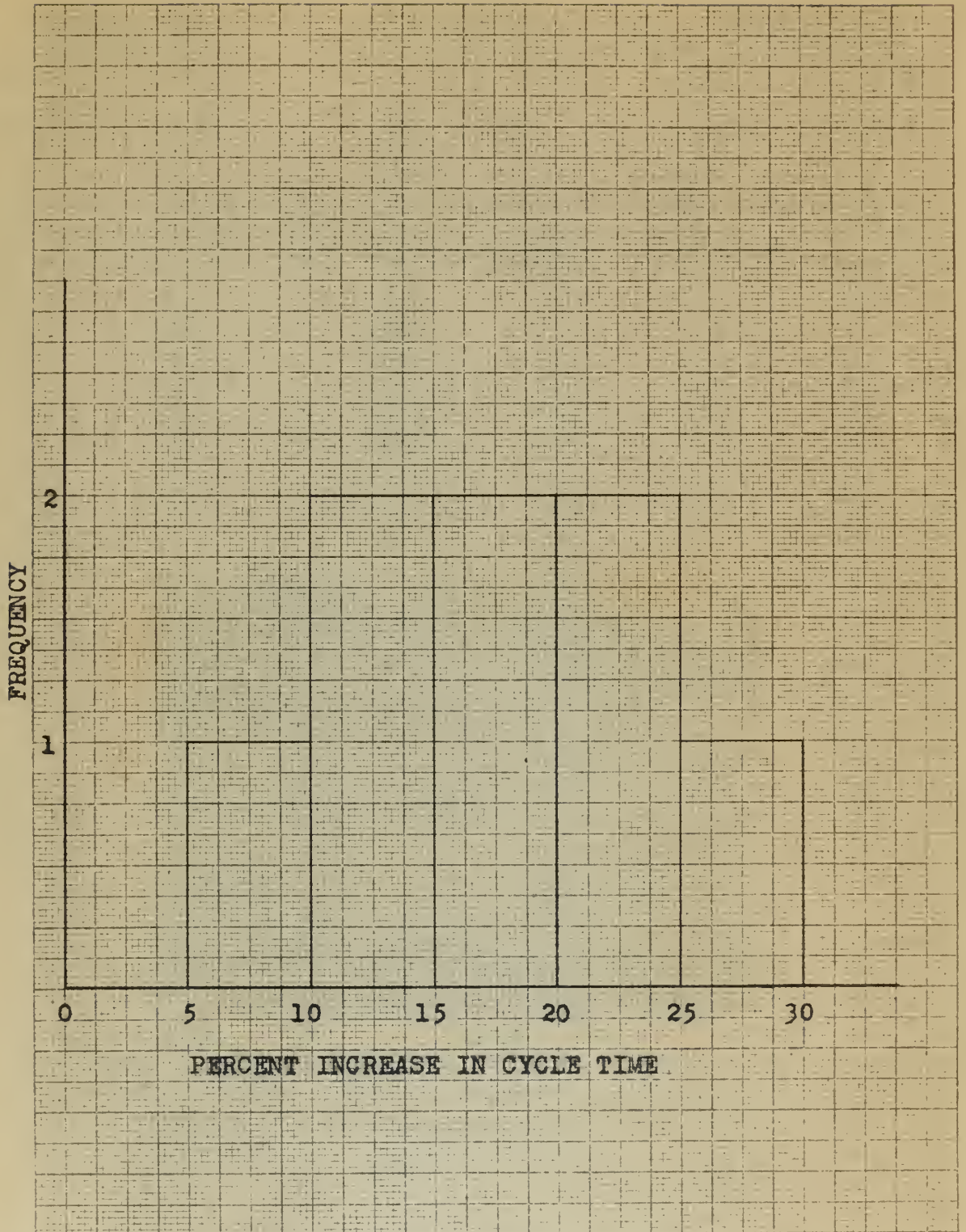


Figure 2. Histogram showing frequency distribution of percent increase in mean cycle time.





Operation: Filling carton with individual boxes of Veto.

Description		
Left Hand	Therblig	Right Hand
Get box of Veto	TE, <u>Q</u> , TL	Get box of Veto
Place in carton	P, A, RL	Place in carton

The therblig underlined performed by the right hand is the beginning of the cycle for the purposes of this time analysis.



Figure 3. Workplace for Packaging Veto.

operation: filling section with individual boxes of tape.

Left Hand	Shedding	Right Hand
Get box of tape	Get box of tape	Get box of tape
Place in section	Place in section	Place in section

The shedding operation performed by the right hand is the  
beginning of the cycle for the purpose of this time study  
via



Figure 3. Shedding for recording tape.

Table 3  
VETO PACKAGING #1

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
595		315		784	
630	35	369*		814	30
675	35	013*		845	31
768*		049	36	876	31
806	38	573*		911	35
919*		566	29	132*	
954	35	616*		165	33
000*		665*		200	35
036	36	697*		247*	
069	33	728	31	273	26
230*		867*		300	27
267	37	897	30	330	30
307	40	955*		373*	
351*		030*		411*	
385	34	068*		543	32
423	38	100	32	575	32
572*		144*		606	31
612*		171	27	640	36
650	38	205	34	675	35
682	32	235	30	703	28
729*		265	30	734	31
840*		302	37	761	27
872	32	393*		793	32
912	40	434*		827	34
950	38	464	30	860	33
978	28	575*		022*	
026*		548	33	050	28
315*		574	26	078	28
350	35	620*		116*	
386	36	650	30	154*	
516*		680	30	185	31
601*		710	30	236*	
642	41	740	30	267	31
855*		771	31	300	33
895	40	848*		332	32
940*		888*		074*	
975	35	920	32	413*	
011	36	960*		549*	
		996	36	583	34
		024	28	615	32
		056	32	650	35
		086	30	685	35
		130*		720	35
		160	30	752	32
		193	33	780	28
		226	33	812	32
		323*		840*	
		351	28	871	31
		378	27	046*	
		415*		078	32
				111	33
				150*	
				188*	
				222	34

---

$\Sigma t$	792	865	1205
N	22	28	38
$\bar{t}$	36.000	30.893	31.710

T = elapsed time, t = cycle time, N = number of cycles  
 $\bar{t}$  = mean cycle time. Note: Symbols apply to Tables 3 - 10.  
 \*Cycle time not included because of fumble or irregularly occurring element.





Table 4  
VETO PACKAGING #2

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
210*		380		745	
253*		406	26	770	25
293	40	456*		793	23
327	34	509*		818	25
377*		535	26	847	29
473*		558	23	860*	
510	37	591	33	885	25
549	39	621	30	055*	
587	38	652	31	095*	
622	35	743*		125	30
658	36	770	27	158	33
753*		797	27	183	25
792	39	830	33	208	25
830	38	865	35	245	37
869	39	897	32	269	24
911*		936*		294	25
948	37	964	28	376*	
033*		985	21	405	29
065	32	008	23	434	29
099	34	037	29	463	29
158*		059*		493	30
187	29	092	33	528	35
218	31	192*		560	32
300*		220	28	586	26
334	34	968*		612	26
376*		352*		640	28
410	34	380	28	668	28
442	32	411	31	695	27
469	27	436	25	787*	
550*		460	24	826*	
580	30	490	30	856	30
622*		520	30	885	29
659	37	552	32	966*	
693	34	638*		005*	
728	35	664	26	034	29
825*		690	26	067	33
857	32	740*		110*	
895	38	785*		148*	
934	39	828*		177	29
962	28	867*		296*	
990	28	946*		225	29
083*		974	28	254	29
122	39	998	24	284	30
157	35	085*		324*	
193	36	111	26	452	28
223	30	142	31	480	28
250	27	172	30	507	27
		202	30	532	25
		234	32	557	25
		264	30	587	30
		291	27		
		317	26		
		361*			
		386	25		
		412	26		
<hr/> $\Sigma t$		1072		1046	
$N$		38		37	
$\bar{t}$		28.210		28.270	
	1133				
	33				
	34.333				

\*Cycle time not included because of fumble or irregularly occurring element.

TABLE  
OF OBSERVATIONS

1900-1901		1901-1902		1902-1903	
1	2	1	2	1	2
100	100	100	100	100	100
90	90	90	90	90	90
80	80	80	80	80	80
70	70	70	70	70	70
60	60	60	60	60	60
50	50	50	50	50	50
40	40	40	40	40	40
30	30	30	30	30	30
20	20	20	20	20	20
10	10	10	10	10	10
0	0	0	0	0	0
10	10	10	10	10	10
20	20	20	20	20	20
30	30	30	30	30	30
40	40	40	40	40	40
50	50	50	50	50	50
60	60	60	60	60	60
70	70	70	70	70	70
80	80	80	80	80	80
90	90	90	90	90	90
100	100	100	100	100	100
10	10	10	10	10	10
20	20	20	20	20	20
30	30	30	30	30	30
40	40	40	40	40	40
50	50	50	50	50	50
60	60	60	60	60	60
70	70	70	70	70	70
80	80	80	80	80	80
90	90	90	90	90	90
100	100	100	100	100	100
10	10	10	10	10	10
20	20	20	20	20	20
30	30	30	30	30	30
40	40	40	40	40	40
50	50	50	50	50	50
60	60	60	60	60	60
70	70	70	70	70	70
80	80	80	80	80	80
90	90	90	90	90	90
100	100	100	100	100	100



Table 5  
VETO PACKAGING #3

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
265*		142*		227*	
308	43	193*		251	24
347	39	246*		282	31
403*		304*		324*	
446	43	337	33	356	32
555*		376	39	566*	
590	35	426*		598	32
631	41	486*		632	34
670	39	531*		666	34
707	37	562	31	699	33
750	43	623*		742*	
837*		670*		770	28
877	40	705	35	799	29
938*		737	32	830	31
985	47	450*		863	33
049*		492	42	894	31
084	35	528	36	043*	
201*		565	37	075	32
237	36	635*		108	33
275	38	759*		142	34
346*		789	30	175	33
384	38	813	24	215	40
422	38	843	30	249	34
547*		876	33	280	31
586	39	962*		314	34
624	38	992	30	345	31
664	40	025	33	376	31
708	44	064	39	428*	
747	39	094	30	573*	
863*		130	36	613	40
900	37	172	42	666*	
938	38	202	30	696	30
977	39	237	35	736	40
015	38	270	33	767	31
054	39	300	30	804	37
166*		330	30	836	32
206	40	443*		878	42
255	49	470	27	921	43
328*		496	26	958	37
367	39	527	31	989	31
415	48	560	33	145*	
507*		596	36	174	29
552	45	628	32	202	28
		659	31	248*	
		687	28		
		715	28		
		757	42		
		782	25		
		899*			
		930	31		
		961	31		
		004	43		
		046	42		
		092*			
		125	33		
<hr/> $\Sigma t$		<hr/> $\Sigma t$		<hr/> $\Sigma t$	
$N$		$N$		$N$	
$\bar{t}$		$\bar{t}$		$\bar{t}$	
1204		1289		1125	
30		39		34	
40.133		33.051		33.088	

\*Cycle time not included because of fumble or irregularly occurring element.





Operation: Filling carton with individual tooth powder cans.

### Description

Left Hand	Therblig	Right Hand
Get can of tooth powder	TE, <u>Q</u> , TL	Get can of tooth powder
Place in carton	P, A, RL	Place in carton

The underlined therblig performed by the right hand is the start of the work cycle for the purpose of this time analysis.



Figure 4. Workplace for tooth powder packaging.

Operation: Fill the can with tooth powder and seal.

# Preparation

Left Hand	Right Hand	Left Hand
Get out of tooth powder 1/2, 1/2, 1/2	Get out of tooth powder 1/2, 1/2, 1/2	Get out of tooth powder 1/2, 1/2, 1/2
Place in can	Place in can	Place in can

The material should be prepared by the right hand is the  
start of the work for the purpose of this time only.  
M.A.



Figure 1. Material for tooth powder preparation.

Table 6

## TOOTH POWDER PACKAGING #1

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
602*		540*		368*	
681*		567	27	405*	
730*		619*		439	34
762	32	649	30	560*	
888*		677	28	590	30
927	39	707	30	616	26
976*		735	28	647	31
015	39	764	29	687*	
092*		795	31	718	31
123	31	822	27	761*	
255*		945*		802*	
287	32	976	31	832	30
324	37	004	28	862	30
360	36	035	31	891	29
406*		064	29	929*	
570*		095	31	036*	
601	31	124	29	076*	
635	34	155	31	110	34
670	35	192*		140	30
705	35	222	30	184*	
738	33	255	33	248*	
879*		445*		280	32
918	39	535*		330*	
952	34	570	35	372*	
023*		670*		407	35
123*		702	32	444	37
265*		734	32	475	31
295	30	762	28	611*	
330	35	793	31	645	34
377*		825	32	684*	
415	38	926*		725*	
455	40	957	31	764*	
608*		985	28	795	31
645*		017	32	827	32
686*		055*		857	30
728*		085	30	887	30
761	33	117	32	918	31
805*		147	30	953	35
926*		183	36	984	31
982*		216	33	155*	
		246	30	183	28
		288*		213	30
		425*		247	34
		454	29	287*	
		492*		318	31
		522	30	351	33
		554	32	385	34
		585	31		
		626*			
		685*			
		720	35		
		751	31		
		781	30		
		930*			
		956	26		
		986	30		
<hr/>		<hr/>		<hr/>	
$\Sigma t$	663	1249		884	
$\frac{N}{t}$	19	41		28	
	34.895	30.504		31.571	

\*Cycle time not included because of fumble or irregularly occurring element.



Weekly Average Temperature in

Temperature		Precipitation		Wind-velocity	
1	2	1	2	1	2
80.0	80.0	0.0	0.0	0.0	0.0
80.0	80.0	0.0	0.0	0.0	0.0
79.0	79.0	0.0	0.0	0.0	0.0
78.0	78.0	0.0	0.0	0.0	0.0
77.0	77.0	0.0	0.0	0.0	0.0
76.0	76.0	0.0	0.0	0.0	0.0
75.0	75.0	0.0	0.0	0.0	0.0
74.0	74.0	0.0	0.0	0.0	0.0
73.0	73.0	0.0	0.0	0.0	0.0
72.0	72.0	0.0	0.0	0.0	0.0
71.0	71.0	0.0	0.0	0.0	0.0
70.0	70.0	0.0	0.0	0.0	0.0
69.0	69.0	0.0	0.0	0.0	0.0
68.0	68.0	0.0	0.0	0.0	0.0
67.0	67.0	0.0	0.0	0.0	0.0
66.0	66.0	0.0	0.0	0.0	0.0
65.0	65.0	0.0	0.0	0.0	0.0
64.0	64.0	0.0	0.0	0.0	0.0
63.0	63.0	0.0	0.0	0.0	0.0
62.0	62.0	0.0	0.0	0.0	0.0
61.0	61.0	0.0	0.0	0.0	0.0
60.0	60.0	0.0	0.0	0.0	0.0
59.0	59.0	0.0	0.0	0.0	0.0
58.0	58.0	0.0	0.0	0.0	0.0
57.0	57.0	0.0	0.0	0.0	0.0
56.0	56.0	0.0	0.0	0.0	0.0
55.0	55.0	0.0	0.0	0.0	0.0
54.0	54.0	0.0	0.0	0.0	0.0
53.0	53.0	0.0	0.0	0.0	0.0
52.0	52.0	0.0	0.0	0.0	0.0
51.0	51.0	0.0	0.0	0.0	0.0
50.0	50.0	0.0	0.0	0.0	0.0
49.0	49.0	0.0	0.0	0.0	0.0
48.0	48.0	0.0	0.0	0.0	0.0
47.0	47.0	0.0	0.0	0.0	0.0
46.0	46.0	0.0	0.0	0.0	0.0
45.0	45.0	0.0	0.0	0.0	0.0
44.0	44.0	0.0	0.0	0.0	0.0
43.0	43.0	0.0	0.0	0.0	0.0
42.0	42.0	0.0	0.0	0.0	0.0
41.0	41.0	0.0	0.0	0.0	0.0
40.0	40.0	0.0	0.0	0.0	0.0
39.0	39.0	0.0	0.0	0.0	0.0
38.0	38.0	0.0	0.0	0.0	0.0
37.0	37.0	0.0	0.0	0.0	0.0
36.0	36.0	0.0	0.0	0.0	0.0
35.0	35.0	0.0	0.0	0.0	0.0
34.0	34.0	0.0	0.0	0.0	0.0
33.0	33.0	0.0	0.0	0.0	0.0
32.0	32.0	0.0	0.0	0.0	0.0
31.0	31.0	0.0	0.0	0.0	0.0
30.0	30.0	0.0	0.0	0.0	0.0
29.0	29.0	0.0	0.0	0.0	0.0
28.0	28.0	0.0	0.0	0.0	0.0
27.0	27.0	0.0	0.0	0.0	0.0
26.0	26.0	0.0	0.0	0.0	0.0
25.0	25.0	0.0	0.0	0.0	0.0
24.0	24.0	0.0	0.0	0.0	0.0
23.0	23.0	0.0	0.0	0.0	0.0
22.0	22.0	0.0	0.0	0.0	0.0
21.0	21.0	0.0	0.0	0.0	0.0
20.0	20.0	0.0	0.0	0.0	0.0
19.0	19.0	0.0	0.0	0.0	0.0
18.0	18.0	0.0	0.0	0.0	0.0
17.0	17.0	0.0	0.0	0.0	0.0
16.0	16.0	0.0	0.0	0.0	0.0
15.0	15.0	0.0	0.0	0.0	0.0
14.0	14.0	0.0	0.0	0.0	0.0
13.0	13.0	0.0	0.0	0.0	0.0
12.0	12.0	0.0	0.0	0.0	0.0
11.0	11.0	0.0	0.0	0.0	0.0
10.0	10.0	0.0	0.0	0.0	0.0
9.0	9.0	0.0	0.0	0.0	0.0
8.0	8.0	0.0	0.0	0.0	0.0
7.0	7.0	0.0	0.0	0.0	0.0
6.0	6.0	0.0	0.0	0.0	0.0
5.0	5.0	0.0	0.0	0.0	0.0
4.0	4.0	0.0	0.0	0.0	0.0
3.0	3.0	0.0	0.0	0.0	0.0
2.0	2.0	0.0	0.0	0.0	0.0
1.0	1.0	0.0	0.0	0.0	0.0

Table 7

## TOOTH POWDER PACKAGING #2

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
620*		425*		355*	
661	41	459	34	392	37
715*		492	33	440*	
785*		525	33	496*	
829	44	558	33	580*	
917*		593	35	625	45
052*		640*		668	43
095	43	675	35	710	42
181*		734*		765*	
245*		767	33	805	40
292	47	803	36	901*	
345*		914*		944	43
480*		947	33	985	41
525	45	980	33	024	39
572	47	018	38	065	41
635*		054	36	123*	
688*		107*		165	42
737	49	151*		206	41
862*		185	34	248	42
901	39	255*		287	39
949	48	295	40	326	39
129*		332	37	365	39
267*		370	38	482*	
310	43	485*		567*	
370*		554*		637*	
418	48	591	37	680	43
474*		627	36	727	47
522	48	666	39	767	40
647*		711*		805	38
690	43	763*		845	40
740	50	855*		885	40
		885	30	930	45
		985*		970	40
		094*		105	35
		132	38	147	42
		170	38	182	35
		197	27	230*	
		232	35	283*	
		270	38	326	43
		299	29	365	39
		345*		438*	
		382	37	490*	
		419	37	532	42
		452	33	574	42
		485	33	640	36
		584*			
		620	36		
		650	30		
		689	39		
		723*			
		760	37		
<hr/>		<hr/>		<hr/>	
$\Sigma t$	635	1190		1259	
$N$	14	34		31	
$\bar{t}$	45.357	35.000		40.533	

\*Cycle time not included because of fumble or irregularly occurring element.

## TABLE

OF THE RESULTS OF THE SURVEY

STATION		TIME		DISTANCE	
1	2	3	4	5	6
10	1000	10	1000	10	1000
11	1000	11	1000	11	1000
12	1000	12	1000	12	1000
13	1000	13	1000	13	1000
14	1000	14	1000	14	1000
15	1000	15	1000	15	1000
16	1000	16	1000	16	1000
17	1000	17	1000	17	1000
18	1000	18	1000	18	1000
19	1000	19	1000	19	1000
20	1000	20	1000	20	1000
21	1000	21	1000	21	1000
22	1000	22	1000	22	1000
23	1000	23	1000	23	1000
24	1000	24	1000	24	1000
25	1000	25	1000	25	1000
26	1000	26	1000	26	1000
27	1000	27	1000	27	1000
28	1000	28	1000	28	1000
29	1000	29	1000	29	1000
30	1000	30	1000	30	1000
31	1000	31	1000	31	1000
32	1000	32	1000	32	1000
33	1000	33	1000	33	1000
34	1000	34	1000	34	1000
35	1000	35	1000	35	1000
36	1000	36	1000	36	1000
37	1000	37	1000	37	1000
38	1000	38	1000	38	1000
39	1000	39	1000	39	1000
40	1000	40	1000	40	1000
41	1000	41	1000	41	1000
42	1000	42	1000	42	1000
43	1000	43	1000	43	1000
44	1000	44	1000	44	1000
45	1000	45	1000	45	1000
46	1000	46	1000	46	1000
47	1000	47	1000	47	1000
48	1000	48	1000	48	1000
49	1000	49	1000	49	1000
50	1000	50	1000	50	1000
51	1000	51	1000	51	1000
52	1000	52	1000	52	1000
53	1000	53	1000	53	1000
54	1000	54	1000	54	1000
55	1000	55	1000	55	1000
56	1000	56	1000	56	1000
57	1000	57	1000	57	1000
58	1000	58	1000	58	1000
59	1000	59	1000	59	1000
60	1000	60	1000	60	1000
61	1000	61	1000	61	1000
62	1000	62	1000	62	1000
63	1000	63	1000	63	1000
64	1000	64	1000	64	1000
65	1000	65	1000	65	1000
66	1000	66	1000	66	1000
67	1000	67	1000	67	1000
68	1000	68	1000	68	1000
69	1000	69	1000	69	1000
70	1000	70	1000	70	1000
71	1000	71	1000	71	1000
72	1000	72	1000	72	1000
73	1000	73	1000	73	1000
74	1000	74	1000	74	1000
75	1000	75	1000	75	1000
76	1000	76	1000	76	1000
77	1000	77	1000	77	1000
78	1000	78	1000	78	1000
79	1000	79	1000	79	1000
80	1000	80	1000	80	1000
81	1000	81	1000	81	1000
82	1000	82	1000	82	1000
83	1000	83	1000	83	1000
84	1000	84	1000	84	1000
85	1000	85	1000	85	1000
86	1000	86	1000	86	1000
87	1000	87	1000	87	1000
88	1000	88	1000	88	1000
89	1000	89	1000	89	1000
90	1000	90	1000	90	1000
91	1000	91	1000	91	1000
92	1000	92	1000	92	1000
93	1000	93	1000	93	1000
94	1000	94	1000	94	1000
95	1000	95	1000	95	1000
96	1000	96	1000	96	1000
97	1000	97	1000	97	1000
98	1000	98	1000	98	1000
99	1000	99	1000	99	1000
100	1000	100	1000	100	1000

Operation: Filling carton with bottles of Halo.

Description		
Left Hand	Therblig	Right Hand
Get bottle of Halo	TE, <u>G</u> , TL	Get bottle of Halo
Place in carton	P, A, RL	Place in carton

The therblig underlined performed by the right hand represents the start of a cycle for the purpose of this time analysis.



Figure 5. Workplace for Packaging Halo.



Operation: filling carton with bottles of milk.

Operation:

Left hand	Right hand
Get bottle of milk	Get bottle of milk
Place in carton	Place in carton

The charting suggested performed by the right hand represents the start of a cycle for the purpose of this time analysis.



Figure 2. Sequence for filling milk.

Table 8  
HALO PACKAGING

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
499*		872*		890*	
544	45	911	39	931	41
673*		960*		973	42
712	39	040*		040*	
756	44	085	45	090*	
795	39	124	39	132	42
835	40	257*		170	38
878	43	300	43	220*	
136*		337	37	282*	
185	49	372	35	333*	
218	33	423*		388*	
258	40	459	36	523*	
302	44	498	39	563	40
422*		540	42	610	47
460	38	578	38	652	42
502	42	624	46	717*	
542	40	664	40	757	40
582	40	699	35	808*	
628	46	828*		847	39
754*		878*		905*	
796	42	916	38	960*	
842	46	955	39	010*	
880	38	008*		065*	
920	40	046	38	227*	
979*		085	39	265	38
107*		122	37	307	42
148	41	235*		347	40
189	41	274	39	459*	
226	37	312	38	495	36
264	38	438*		540	45
310	46	474	36	575	35
417*		513	39	618	43
454	37	549	36		
528*		599*			
564	36	636	37		
603	39	673	37		
656*		711	38		
796*		748	37		
836	40	790	42		
877	41	827	37		
917	40	863	37		
960	43	003	40		
007	47	037	34		
131*		068	31		
172	41	102	34		
216	44				
263	47				
310	47				
357	47				

---

$\Sigma t$	1540	1297	650
$\frac{N}{t}$	37	34	16
$\bar{t}$	41.621	38.147	40.625

\*Cycle time not included because of fumble or irregularly occurring element.

Table 2

1947-1948		1948-1949		1949-1950	
1	2	1	2	1	2
100	100	100	100	100	100
95	95	95	95	95	95
90	90	90	90	90	90
85	85	85	85	85	85
80	80	80	80	80	80
75	75	75	75	75	75
70	70	70	70	70	70
65	65	65	65	65	65
60	60	60	60	60	60
55	55	55	55	55	55
50	50	50	50	50	50
45	45	45	45	45	45
40	40	40	40	40	40
35	35	35	35	35	35
30	30	30	30	30	30
25	25	25	25	25	25
20	20	20	20	20	20
15	15	15	15	15	15
10	10	10	10	10	10
5	5	5	5	5	5
0	0	0	0	0	0
100	100	100	100	100	100
95	95	95	95	95	95
90	90	90	90	90	90
85	85	85	85	85	85
80	80	80	80	80	80
75	75	75	75	75	75
70	70	70	70	70	70
65	65	65	65	65	65
60	60	60	60	60	60
55	55	55	55	55	55
50	50	50	50	50	50
45	45	45	45	45	45
40	40	40	40	40	40
35	35	35	35	35	35
30	30	30	30	30	30
25	25	25	25	25	25
20	20	20	20	20	20
15	15	15	15	15	15
10	10	10	10	10	10
5	5	5	5	5	5
0	0	0	0	0	0
100	100	100	100	100	100
95	95	95	95	95	95
90	90	90	90	90	90
85	85	85	85	85	85
80	80	80	80	80	80
75	75	75	75	75	75
70	70	70	70	70	70
65	65	65	65	65	65
60	60	60	60	60	60
55	55	55	55	55	55
50	50	50	50	50	50
45	45	45	45	45	45
40	40	40	40	40	40
35	35	35	35	35	35
30	30	30	30	30	30
25	25	25	25	25	25
20	20	20	20	20	20
15	15	15	15	15	15
10	10	10	10	10	10
5	5	5	5	5	5
0	0	0	0	0	0

Operation: Assembling faucet sub-assembly.

Description		
Left Hand	Therblig	Right Hand
Get saw	TE, G, P	Get saw
Assemble with fixture	A, RL	Assemble with fixture
Get washer	TE, G, TL	Get washer
Assemble with screw	P, A, RL	Assemble with screw
Get swivel	TE, G, P	Get swivel
Assemble with screw	A, RL	Assemble with screw
Disassemble from fixture	TE, G, TL	Disassemble from fixture
Assemble with tighten- ing board	P, <u>A</u> , RL	Assemble with tighten- ing board

The underlined Therblig represents the performed act by the right hand beginning a cycle for the purposes of this time analysis.



Figure 6. Workplace for assembling faucet sub-assemblies.



Operation: Assembly of the engine.

Procedure

Step	Operation	Time
1	Get new	1.0
2	Assembly with	1.0
3	Get washer	1.0
4	Assembly with	1.0
5	Get valve	1.0
6	Assembly with	1.0
7	Assembly from	1.0
8	Assembly with	1.0
9	Get board	1.0

The underlined words represent the performed work by the right hand beginning a cycle for the purpose of this time analysis.



Figure 8. Workplace for assembling the engine.

Table 9

## FAUCET SUB-ASSEMBLY

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
238*		118*		988*	
501	263	372	254	212	224
725	224	590	218	436	224
980	255	808	218	662	226
259	271	043	235	876	214
495	236	308*		160*	
759	264	511	203		
024	265	725	214		
426*		922	197		
696	270	317*			
985*		530	213		
410*		796*			
700*		035	239		
926	226	284	249		
140	214	456*			
391	251	741*			
689*		770*			
065*		981	211		
328	263				
626*					
<hr/>					
$\Sigma t$	3002	2451		888	
$N$	12	11		4	
$\bar{t}$	250.167	222.154		222.000	

\*Cycle time not included because of fumble or irregularly occurring element.



Operation: Assembling watt-hour meter sub-assembly.

### Description

Left Hand	Therblig	Right Hand
Get sleeve	TE, G, TL	Get sleeve
Assemble with fixture	P, A, RL	Assemble with fixture
Get washer	TE, G, TL	Get washer
Assemble with fixture	P, A, RL	Assemble with fixture
Get screw	TE, G, TL	Get screw
Assemble with sleeve and washer	P, A, RL <u>DA</u> , RL	Assemble with sleeve and washer Trip fixture release

The therblig underlined performed by the right hand represents the beginning of a cycle for the purpose of this time analysis.



Figure 7. Workplace for assembling watt-hour meter sub-assembly.



Inspected

Left Hand	Throttle	Right Hand
Get screw	7.5, 0.75	Get screw
Assembly with fixture	7.5, 0.75	Assembly with fixture
Get washer	7.5, 0.75	Get washer
Assembly with fixture	7.5, 0.75	Assembly with fixture
Get screw	7.5, 0.75	Get screw
Assembly with fixture	7.5, 0.75	Assembly with fixture
Get washer	7.5, 0.75	Get washer
Assembly with fixture	7.5, 0.75	Assembly with fixture

The throttle assembly is performed by the right hand worker. The beginning of a cycle for the purpose of this time analysis.



Figure 5. Assembly for assembling well-head water sub-assembly.

Table 10

## ASSEMBLING SLEEVE AND WASHER TO BOLT

<u>Bimanually</u>		<u>Preferred Hand</u>		<u>Non-Preferred Hand</u>	
<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>	<u>T</u>	<u>t</u>
750*		037*		707*	
918	168	235	198	874	167
135	217	427	192	054	180
352*		553	126	179	125
598*		740	187	316	137
788	190	867	127	483	167
009	221	135	168	645	162
152	143	255*		810	165
556*		430	175	958	148
775	219	586	156	093	135
915	140	740	154	231	138
084	169	874	136	380	149
239	155	059	185	526	146
385	146	237	178	654	128
580	195	704*		785	131
791	211	874	170	930	145
960	169	015	141	111	181
103	143	152	137	647*	
338*		304	152	867*	
496	158	456	152	996	129
656	160	617	161	177	181
841	185	742	125	326	149
011	170	876	134	480	154
211	200	012	136		
770*					
946	176				
089	143				
234	145				
431	197				
601	171				
805	204				
009	204				
237*					
404	167				
594	190				
775	181				
962	187				
139	177				
<hr/>					
$\Sigma t$	5501	3290		3017	
$\frac{N}{t}$	31	21		20	
$\bar{t}$	177.452	156.667		150.850	

\*Cycle time not included because of fumble or irregularly occurring element.





Table 11  
CALCULATION OF  $N^1$

Operation	Operator		$\Sigma t$	$\Sigma t^2$	$N \Sigma t^2$	
1	1	Preferred Hand	865	26921	753788	
		Non-preferred	1205	38459	1461442	
		Bimanually	792	28716	631752	
	2	Preferred Hand	1082	30644	1164472	
		Non-preferred	1046	29916	1106892	
		Bimanually	1133	39391	1299903	
	3	Preferred Hand	1289	43515	1697085	
		Non-preferred	1125	37791	1284894	
		Bimanually	1204	48692	1460760	
2	1	Preferred Hand	1249	38235	1567635	
		Non-preferred	884	28064	785792	
		Bimanually	663	23307	442833	
	2	Preferred Hand	1190	41960	1426640	
		Non-preferred	1216	49486	1484580	
		Bimanually	635	28941	405174	
3	1	Preferred Hand	1297	49779	1692486	
		Non-preferred	650	26550	424800	
		Bimanually	1540	64586	2389682	
4	1	Preferred Hand	2888	549615	60457650	
		Non-preferred	888			
		Bimanually	3002	755370	9064440	
5	1	Preferred Hand	3017	461381	9227620	
		Non-preferred	3290	526104	11048184	
		Bimanually	5501	994191	30819921	
			$(\Sigma t)^2$	$N \Sigma t^2 - (\Sigma t)^2$	N	$N^1$
1	1	Preferred Hand	748225	5563	28	11.9
		Non-preferred	1452025	9417	38	10.4
		Bimanually	627264	4488	22	11.4
	2	Preferred Hand	1149184	15288	38	20.9
		Non-preferred	1094116	12776	37	18.7
		Bimanually	1283689	16214	33	20.25
	3	Preferred Hand	1661521	35564	39	34.3
		Non-preferred	1265625	19269	34	24.3
		Bimanually	1449616	11144	30	12.3
2	1	Preferred Hand	1560001	7634	41	7.9
		Non-preferred	781456	4336	28	10.0
		Bimanually	439569	3264	19	11.9
	2	Preferred hand	1416100	10540	34	11.9
		Non-preferred	1478656	5924	30	6.4
		Bimanually	403225	1949	14	7.4
3	1	Preferred Hand	1682209	10277	34	10.1
		Non-preferred	422500	2300	16	8.7
		Bimanually	2371600	18082	37	12.2



Year	Age	Sex	Weight (kg)	Length (cm)	Condition
1975	10	M	10.5	110	Good
1976	11	F	11.2	115	Good
1977	12	M	12.8	120	Good
1978	13	F	13.5	125	Good
1979	14	M	14.2	130	Good
1980	15	F	15.1	135	Good
1981	16	M	16.3	140	Good
1982	17	F	17.5	145	Good
1983	18	M	18.2	150	Good
1984	19	F	19.1	155	Good
1985	20	M	20.5	160	Good
1986	21	F	21.3	165	Good
1987	22	M	22.8	170	Good
1988	23	F	23.5	175	Good
1989	24	M	24.2	180	Good
1990	25	F	25.1	185	Good
1991	26	M	26.3	190	Good
1992	27	F	27.5	195	Good
1993	28	M	28.2	200	Good
1994	29	F	29.1	205	Good
1995	30	M	30.5	210	Good

$\lambda$	$\mu$	$\frac{1}{2}(\lambda + \mu)$	$\frac{1}{2}(\lambda - \mu)$	$\frac{1}{2}(\lambda + \mu)$	$\frac{1}{2}(\lambda - \mu)$
0.11	0.01	0.06	0.05	0.06	0.05
0.12	0.02	0.07	0.05	0.07	0.05
0.13	0.03	0.08	0.05	0.08	0.05
0.14	0.04	0.09	0.05	0.09	0.05
0.15	0.05	0.10	0.05	0.10	0.05
0.16	0.06	0.11	0.05	0.11	0.05
0.17	0.07	0.12	0.05	0.12	0.05
0.18	0.08	0.13	0.05	0.13	0.05
0.19	0.09	0.14	0.05	0.14	0.05
0.20	0.10	0.15	0.05	0.15	0.05

Table 11 (Continued)

Operation	Operator		$(\sum t)^2$	$\frac{N \sum t^2}{(\sum t)^2}$	N	$N^1$
4	1	Preferred Hand	6007401	38364	11	10.1
		Non-preferred			4	
		Bimanually	9012004	52436	12	9.3
5	1	Preferred Hand	9102289	125331	20	22
		Non-preferred	1082410	224084	21	33
		Bimanually	30261001	558920	31	29.4

Table 11 (continued)

Year	Age	Sex	Weight (kg)	Length (cm)	Condition	Notes
1971	11	M	55.5	107.0	Good	
1971	11	F	55.5	107.0	Good	
1971	11	M	55.5	107.0	Good	
1971	11	F	55.5	107.0	Good	
1971	11	M	55.5	107.0	Good	
1971	11	F	55.5	107.0	Good	
1971	11	M	55.5	107.0	Good	
1971	11	F	55.5	107.0	Good	
1971	11	M	55.5	107.0	Good	
1971	11	F	55.5	107.0	Good	

Table 12

COMPUTATION OF CORRELATION COEFFICIENT  
 BETWEEN MEAN CYCLE TIMES FOR PREFERRED HAND OPERATION  
 AND PERCENT INCREASE IN CYCLE TIME FOR BIMANUAL OPERATION

Operation	Operator	Cycle Time	Percent Increase
		x	y
1	1	30.893	16.531
	2	28.210	21.705
	3	33.051	21.427
2	1	30.463	14.549
	2	35.000	29.591
3	1	38.147	9.107
4	1	222.818	12.610
5	1	150.850	17.635

$\Sigma x$  569.432  
 $\Sigma x^2$  78829.607  
 $\Sigma x \Sigma y$  81325.709

$\Sigma y$  143.155  
 $\Sigma y^2$  2843.741  
 $\Sigma xy$  9127.445

Line of Least Squares.

$$a = \text{slope} = \frac{N \Sigma xy - \Sigma x \Sigma y}{N \Sigma x^2 - (\Sigma x)^2} = -.027$$

$$b = y \text{ intercept} = \frac{\Sigma x^2 \Sigma y - \Sigma x \Sigma xy}{N \Sigma x^2 - (\Sigma x)^2} = 15.972$$



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OPERATION OF COMMISSION COMPANIES  
 BETWEEN 1900 AND 1905  
 AND PRESENT INCREASE IN COSTS FOR AVERAGE OPERATION

Operation Company	Year	Present Increase
1	1	10.000
2	2	10.000
3	3	10.000
4	4	10.000
5	5	10.000
6	6	10.000
7	7	10.000
8	8	10.000
9	9	10.000
10	10	10.000
11	11	10.000
12	12	10.000
13	13	10.000
14	14	10.000
15	15	10.000
16	16	10.000
17	17	10.000
18	18	10.000
19	19	10.000
20	20	10.000
21	21	10.000
22	22	10.000
23	23	10.000
24	24	10.000
25	25	10.000
26	26	10.000
27	27	10.000
28	28	10.000
29	29	10.000
30	30	10.000
31	31	10.000
32	32	10.000
33	33	10.000
34	34	10.000
35	35	10.000
36	36	10.000
37	37	10.000
38	38	10.000
39	39	10.000
40	40	10.000
41	41	10.000
42	42	10.000
43	43	10.000
44	44	10.000
45	45	10.000
46	46	10.000
47	47	10.000
48	48	10.000
49	49	10.000
50	50	10.000
51	51	10.000
52	52	10.000
53	53	10.000
54	54	10.000
55	55	10.000
56	56	10.000
57	57	10.000
58	58	10.000
59	59	10.000
60	60	10.000
61	61	10.000
62	62	10.000
63	63	10.000
64	64	10.000
65	65	10.000
66	66	10.000
67	67	10.000
68	68	10.000
69	69	10.000
70	70	10.000
71	71	10.000
72	72	10.000
73	73	10.000
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75	75	10.000
76	76	10.000
77	77	10.000
78	78	10.000
79	79	10.000
80	80	10.000
81	81	10.000
82	82	10.000
83	83	10.000
84	84	10.000
85	85	10.000
86	86	10.000
87	87	10.000
88	88	10.000
89	89	10.000
90	90	10.000
91	91	10.000
92	92	10.000
93	93	10.000
94	94	10.000
95	95	10.000
96	96	10.000
97	97	10.000
98	98	10.000
99	99	10.000
100	100	10.000

Line of best fit.

$$a = \text{slope} = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2}$$

$$b = \text{intercept} = \frac{\sum y_i - a \sum x_i}{n}$$

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and two-handed industrial  
work.

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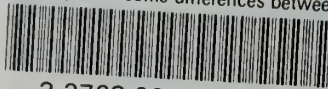
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